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OPTIMIZATION OF AUTOMOBILE TRANSPORTATION BY MEANS OF GIS (ON AN EXAMPLE OF RIVNE REGION)

T. Dets, S. Trokhymets
National University of Water Management and Nature Resources Use, Rivne

Yu. Okrenets
Kamaz-Trans-Service Ltd, Rivne

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The problem

Road transport is an important part of the Ukrainian transport system for the transport of passengers and cargo and the impact on the economy and society. The state of highways of Ukraine does not meet modern requirements and European standards. Limited financing for the construction, repair and maintenance of roads entails unsatisfactory quality of road surface. According to a report of the World Economic Forum (2014) on global competitiveness, the quality of roads in Ukraine is one of the worst in the world: Our country ranks 139th among 144 countries. For comparison: Poland occupies 89th place (relative to 105th place a year earlier), Georgia – 65 [8].

The market of road transport services is carried out by business entities of all forms of ownership, while the share of private property exceeds 90% [8]. However, managers of different levels in any field have to solve optimization tasks. Before the state and commercial companies that carry goods and passengers in various sectors of the transport industry, the task of planning and optimizing the route of transit is a problem. The result of this task depends on how quickly a large amount of output data can be collected, systematized and analyzed, which can change in time. The main and most convenient tool for this task is GIS-technology.

Geographic information systems are successfully used in major transport companies as part of a system for managing, dispatching and transport planning. Spatial analysis, cartographic modeling, maintaining a single geographic database of various objects with all their attributes and other GIS capabilities can achieve significant cost savings, reduce delivery time, optimally utilize available resources, and improve customer service.

The analysis of recent research and publications that relate to this problem

The main purpose of finding optimal routes for transportation planning is minimization of transport costs, namely means and time [4, 7]. The laying of the same route is not just a path from point A to point B. This is a solution to the transport problem, taking into account many parameters that are constantly changing: load carrying capacity of vehicles, drivers' schedule, road restrictions, etc.

Therefore, the solution of optimization problems in transport logistics involves the use of mathematical apparatus for the analysis and accounting of a significant number of factors [1, 12-15]. However, it is the impossibility of a clear mathematical formalization of most methods for optimizing transportation on transport networks, which leads to the use of modern means of geoinformation technology [5]. The use of GIS in the development of an optimal transport communications plan is a logical continuation of mathematical methods.

Geoinformation systems make it possible to combine mathematical models of transport problems with spatial-territorial attachment and cartographic visualization [3, 6, 9-10].

Taking into account the negative trend of the development of the transport industry of Ukraine and the current state of its road network, the authors of the work are suggested to consider the factor such as the condition of the roadway to optimize road transport by logistics enterprises. To solve these problems, the use of GIS tools is proposed.

Statement of the problem

The aim of the work is to develop a concept for the use of GIS technologies to optimize transportation by road, taking into account the condition of the roadway (for example, Rivne region).

The process of creating geoinformation systems is typical and its stages for the vast majority of GIS are the same. It is necessary to identify the main tasks of the proposed GIS, analyze the flows of information, develop the structure of the profile set of geospatial data and its corresponding layers structure, create a vector map in the software product. The difference may be due to only a few minor features or properties of objects that are investigated when creating GIS.

Creation of a geoinformation system for optimization of road transportation routes on an example of the Rivne region will be carried out in the following four phases:

1) preparatory;
2) development of a conceptual model;
3) technical;
4) testing.

At the preparatory stage, the goal of the future geoinformation system is formed, the tasks that it will perform and the participants that will use it will be identified.

The main purpose of GIS to optimize transportation in road transport is to provide the possibility of operational planning of a route for the carriage of goods or passengers with minimal time and money. In this case, the user must

be able to take into account not only the standard attribute information contained in most navigational charts of different systems, but also the state of the roads (roadway) through which the route runs.

By studying the scope of transportation and analyzing factors that in one measure or another have an effect on the formation of the amount of costs incurred by the carrier in carrying out transport [4-5, 7], the following list of factors was formed:

– category of road;
– road condition;
– vehicle type;
– fuel consumption (depending on the type, mark and model of the vehicle);
– cost of fuel (at each of the filling stations);
– cost of rest, if necessary (parking space);
– weather conditions.

The category of the road through which the planned route will pass influences the amount of traffic costs when transported by the fact that this parameter carries restrictions on the speed, the maximum permissible weight of the vehicle, the number of lanes for traffic, the width of the lane. And the higher the category of road, the cost of overcoming it - less.

The condition of the road surface, especially in Ukraine, plays (without exaggeration) a huge role, since the width of the roadway automatically prevents the movement of the vehicle with the maximum speed allowed for it. Due to limited funding, by 2016, around 90% of public roads have not been repaired for more than 30 years. As a result, 169.6 thousand km of these roads do not meet modern requirements both in terms of durability (39.2%) and in the level of coverage (51.1%) [11]. Based on the statistics presented above, one can conclude that this problem is present in the Rivne region.

The type of vehicle is a parameter that, in some cases and in separate sections of the roads, plays its part in planning the route. This is especially true for large-sized trucks, which are difficult to navigate narrow roads.

Fuel consumption plays a role in trailing the route as a derivative of the vehicle type, since each type (make / model) has its own fuel consumption rate.

The cost of fuel is also part of the future costs of passing the route and has its influence, maybe not significant, but taking it into account when compiling the route for long distances gives quite good indicators of economy.

The cost of a holiday is quite similar to the cost of fuel and its impact is felt when planning long distance transportations.

Weather conditions are a factor which, in the automatic mode, is almost impossible to take into account because of their variability. However, their influence is felt even in the course of transportation for short distances. After all, such phenomena as rain, snow, strong wind and others significantly impede the ability to fully transport the vehicle, even on a high-class road with excellent road conditions.

Since factors such as weather conditions, the cost of fuel and rest are dynamic, and taking into account their parameters in automatic mode is a problematic and time-consuming process, then when planning routes within the Rivne region they will not be taken into account.

The stage of the development of the conceptual model is aimed at analyzing information flows, developing the structure of the profile set of geospatial data and the layered structure corresponding to it.

For a convenient perception of information, we represent the whole process of transportation in road transport using a scenario diagram. This kind of diagrams allows you to create a list of operations that the system will perform, to show the behavior of the system from the standpoint of the third-party user.

To construct a diagram of interaction, we have identified four actors: an automobile company, experts, GIS specialists and consumers.

The road transport company carries out the collection of data on the roads of the study area and checks them. These data include:

– information about all sections of roads within the studied territory (road value, type of coverage, road category, maximum permissible speed of the vehicle, its total weight and maximum permissible dimensions);
– - assessment of the condition of the roadbed, which will be formed on the basis of customer feedback on a specially created site;
– information about all available gas stations for each section of the road (name of the gas station, address, fuel brand with its price, availability of the mini-market, toilet, parking);
– information about all existing parking (address, availability of a mini-market, a toilet, a motel);
– data on border crossing points for international traffic (address, toilet, parking);
– information about the points of charging for toll roads (location, fare).

On the basis of the information collected, the motor transport company independently selects the most expedient parameters for its additional attributes, which will be taken into account when trailing the route for transportation.

Experts are involved in collecting road data along with the previous actor, as well as involved in updating additional attributes of the road network.

GIS specialists carry out the processing of the collected data, take a direct part in the creation of a navigation card and create a transport optimization project itself.

Consumers are involved in the system to replenish current information on the state of the roads, which will be processed by GIS specialists.

Figure 1 shows the sequence of actions that will be taken when creating a geoinformation system for optimizing road transport routes.

From the diagram it is clear that the cycle of system creation is as follows: the motor transport company collects data about the roads within the object of research (Rivne region) and passes it to experts; experts examine the data collected and process them; further GIS specialists create a road map for the navigation, on the basis of which they develop a geoinformation system and transmit the created product and a report to the motor transport company for further use in planning routes for transportation by road.

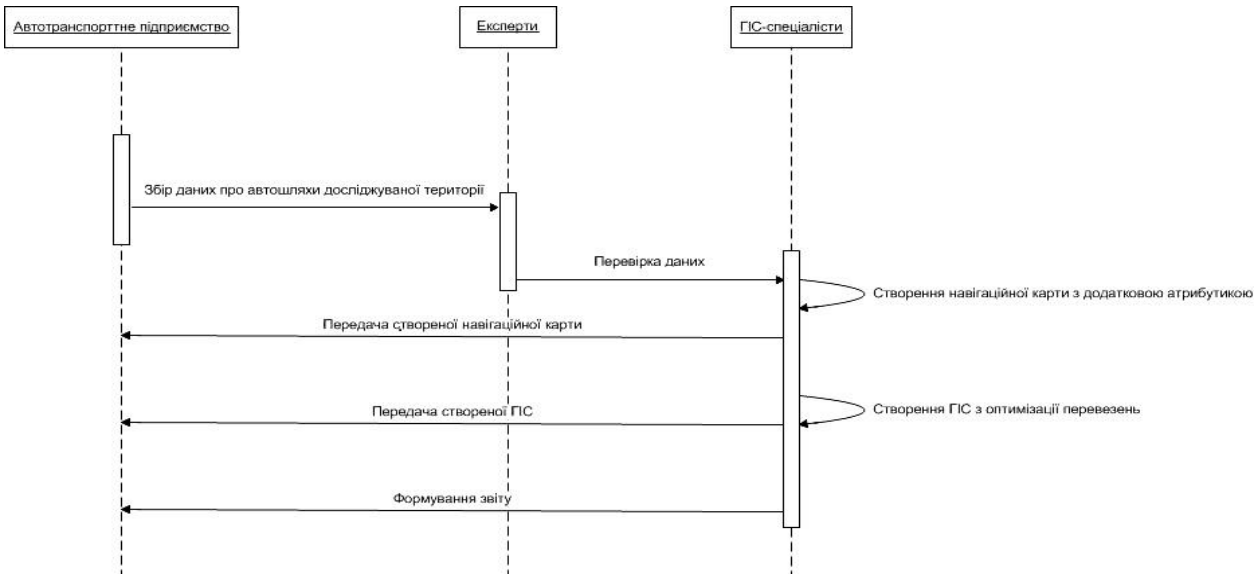

Fig. 1. Diagram of sequence of actions when creating GIS optimization of road transportation

In view of the foregoing, a profile data set was created using a class diagram, which assumes that the geoinformation system for the optimization of traffic in road transport may include not only one navigational card, but several.

The technical stage is the reproduction of the conceptual model of the system. It is one of the most important and complex in the entire system, as the basis for further implementation of the GIS project is formed here. It is necessary to create a digital navigational map of the roads of the study area (in our case, this is the Rivne region). For all roads, assign a typical attribute and auxiliary semantic information, such as: road index, name, road category, lane width, maximum permitted speed, vehicle maximum permissible weight, type of coverage, points of interest with all their characteristics and status assessment road cloth. The navigation map of the territory under investigation is checked for the presence / absence of errors. All these processes are carried out exclusively by GIS specialists, only when additional experts are involved in checking the map. The result should be formed, ready to test the geographic information system.

ArcGIS 10.3 was chosen as the main software of the system in the course of work on creation of GIS optimization of traffic in road transport. This is an advanced and powerful tool for creating and visualizing the map information of Esri, a recognized leader in the market of geographic information systems. Using this toolkit allows you to come up to a different approach to solving different types of tasks.

Transport companies often optimize the route not for a distance, but for the lowest cost of transportation of goods or passengers. This problem is solved by the theory of graphs, where each arc and each node of the network is assigned a certain value. This can be both the average time of the passage of the site, and the factor taking into account the throughput, fuel consumption, the possibility of travel on this site at a certain time or any other parameters.

At the stage of development of the conceptual model of the geographic information system for optimization of road transportation routes, it was found that one of the factors that have the greatest impact on the costs of transportation is the condition of road surface. Therefore it is decided to optimize the routes based on this factor. A similar concept of the geographic information system, which in one way or another solves the problem, is found in [2].

In order to obtain reliable data on the condition of the roads of Rivne region, a group of experts was involved that were made by drivers operating in different transport companies. Experts were asked to assess the state of the roads on a 10-point scale:

1….2 – excellent;
3….5 – good;
6….8 – satisfactory;
9….10 – unsatisfactory coating condition.

As a result of the processing of data obtained from questionnaires of experts, road surface condition indicators have been set, which were entered into the attribute table of all classes of spatial objects of the Road set in the State_Plate field.

For automatic calculation of traffic routes, we have created, with the help of the ArcGIS Network Analyst module, a topologically linked set of network data that includes all available roads. After this, the map can be used for network analysis (routing) in standard navigation mode (based on the standard principles for determining the shortest or fastest route).

The final stage of our work is the testing of the created GIS. It provides for checking the system's performance, as well as providing instructions for its operation.

To check GIS performance optimization of road transportation routes on the map was given 2 points (beginning of route A and the end of route B) and calculated the route. For clarity and confirmation of the correctness of the system, the calculation of the route is executed in 2 principles, using the same network locations:

1) cost (created as a result of optimization);

2) length (the principle of the shortest distance - offered automatically by the software).

The results of route layout are shown in Figures 2 and 3.

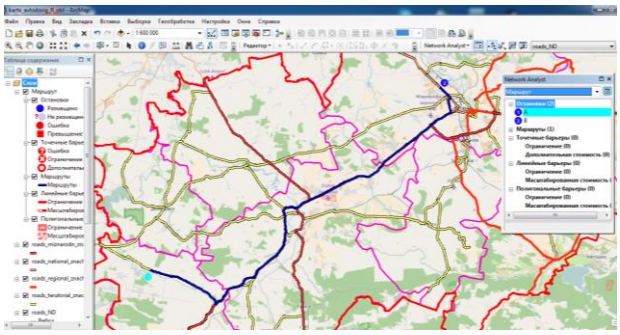

Fig. 2. Route № 1, calculated on the principle of value

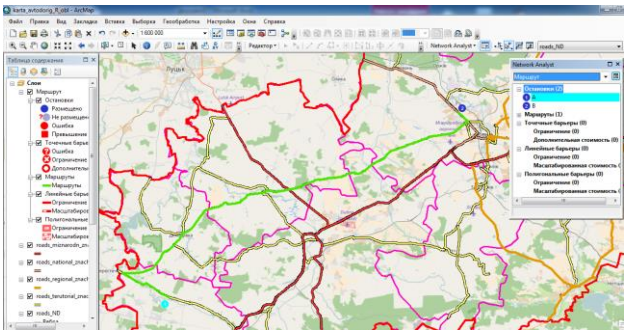

Fig. 3. Route № 2, calculated on the basis of the shortest distance

By comparing both routes with shared starting and ending points visually and along the way sheets (Figure 4-5), it is clear that route number 2 is shorter than route number 1 for 8 km. However, after analyzing the roads through which it is laid out, it becomes clear that they are lower in the category and are significantly worse than the road surface, as opposed to route No. 1.

That is, using route number 2, we risk not only to increase the time of transportation, but also to incur greater material costs.

Conclusions

The developed geoinformation system contains cartographic and attributive materials of the network of highways of Rivne region.

The creation and use of this GIS by small and large transport companies will significantly reduce the material costs of road transport of all types.

In the future, adaptation of the created GIS as a mobile application is planned.

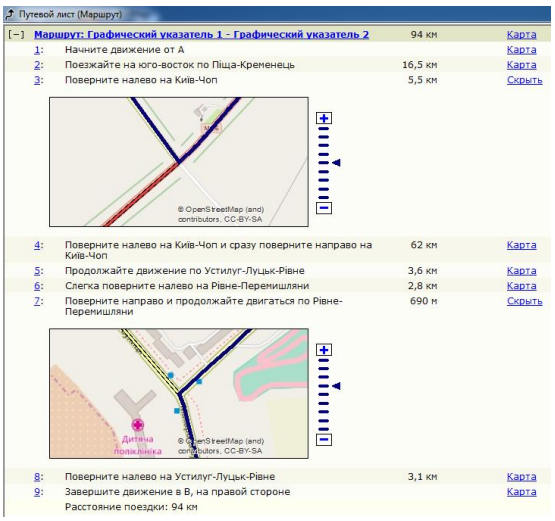

Fig. 4. Route line number 1, calculated on the principle of value

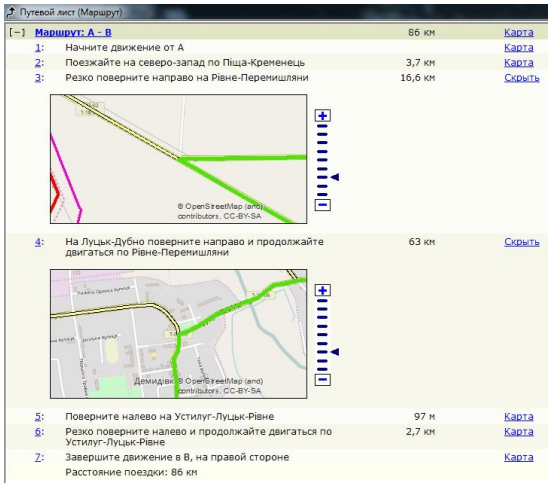

Fig. 5. A route list of route number 2, calculated on the principle of shortest distance

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Optimization of automobile transportation by means of GIS (on an example of Rivne region)

T. Dets, S. Trohymets, Yu. Okrenets

The experience of creating a geographic information system for optimizing road transport by means of GIS is presented. The paper describes the main stages of the solution of a transport problem using GIS-technologies, namely on the basis of ArcGIS software. The proposed model of the system allows to optimize the organization of transport traffic taking into account the condition of the roadway. The developed system is oriented on small and medium logistics enterprises.